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## **Faculty Working Papers**

DYNAMIC MARKET-ORIENTED WORLD FOOD PROJECTION  
AND PLANNING MODELS AND THEIR EMPIRICAL  
RESULTS FOR 1970-1974 WORLD FOOD SITUATION

T. Takayama and H. Hashimoto

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**College of Commerce and Business Administration**  
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January 4, 1977

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THE JOURNAL OF THE  
ROYAL ANTHROPOLOGICAL INSTITUTE  
LONDON  
PUBLISHED BY THE  
INSTITUTE  
1901



Revised December 8, 1976

Dynamic Market-Oriented World Food Projection and Planning Models  
and Their Empirical Results for 1970-1974 World Food Situation\*

by

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## 1. Introduction and a Short Review of Relevant Works

Economic projections have been actively pursued by many government or non-government institutions all over the world especially since 1972. As we all know at this stage, these projection activities have been motivated by the 1972 world-wide shortage of grains and the October 1973 OPEAC embargo of crude oil to the USA.

During the period of three or four years in the past, researchers in this particular field have made full use of their own tools to accomplish this difficult task of projecting or forecasting the future of agricultural commodities and energy resources.

In this short paper, we would like to focus our attention to world food projection and modeling activities, and ignore the energy resource projection and modeling activities even though there are various common features between these two areas.

In the main streams of world food projection works, there are two outstanding approaches we can easily identify. The first one, and most frequently used, is Simulation Approach. Typical examples of this category are:

1) a series of FAO projection works [5], an Iowa State projection work [3], and Michigan State studies [18];

2) the SIMLINK Model used by the World Bank [7] and those compiled in [2].

Usually, simulation models applied to agricultural commodities concentrated on an individual commodity and ignored linkage between this commodity with the rest. This may result in misled conclusions and policy recommendations for some commodities with substantial



substitution possibilities [11]. This weakness is not overcome to a large extent in the SIMLINK modeling yet. International connectiveness of individual countries or regions through commodity movements is not firmly established in the SIMLINK model [7].

The second approach is the Market-Oriented Optimization Approach, which can be classified under the following categories:

- 1) the Japan Ministry of Agriculture projection model, the JAM model hereafter [8];
- 2) the USDA-ERS grain-oilseeds-livestock, or GOL, model [15]; and
- 3) the spatial and temporal price and allocation (STPA) model represented by the Takayama-Liu model for world wheat [21], and the Takayama-Hashimoto model for the eight agricultural commodities and twenty world regions [19].

The JAM model consists of: 1) non-linear and/or linear demand functions, 2) non-linear and/or linear supply functions, 3) price functions, 4) market balance conditions, and 5) inventory generating functions to determine equilibrium (in the sense that the world supply is equal to the world demand for each commodity), prices (one world price for each commodity), consumption and supply quantities and carry-over quantities of wheat, rice, maize, barley, sorghum, millets, soybeans, beef, pork, poultry, and milk every year for 1975 to 1985 for twenty-five regions. Solving a system of mixed, non-linear and linear equations is extremely tedious, but by using the Newton-Raphson iterative approximation method, satisfactory solutions were obtained [8].

The first of the methodological drawbacks is that the livestock sector model is solved independently at the first stage to generate the feed requirements, which are then fed into the grain and oilseeds sector



model as the data. The second drawback is that the model stipulates that the total world demand quantity and total world supply quantity for each commodity must be balanced (after stock adjustment is made) at the world equilibrium price. Thus, practically no country is left without entering into the world trade--an artificial condition needed for solving the system!

The SIMLINK uses international growth models as the scenario generator explicitly, and the JAM model uses a rather primitive manner on some scenarios for growth rates, weather conditions, etc. This leads us to a realization that for dynamical projection activities careful scenario construction is one of the most important corner stones.

The USDA-ERS GOL model depends on 1) a linear structural system for the world grain, oilseeds, and livestock demand, supply, and trade that is the "market" situation for a specific projection year, and 2) a linear programming method to solve the system [15].

Obviously, one-shot scenarios are drawn carefully to represent market situations and macro-economic environments for the specific year.

In this model an integration of livestock, grain, and oilseeds sectors is accomplished, however dynamics, which is the essence of a dynamic simulator, is lost as a result of one-shot projection strategy. Also, the second drawback mentioned in relation to the JAM model still haunts this model.

Our approach is unique in the sense that both the simulation method and the optimization method are utilized in an integrated manner. The dynamic market-oriented models to be developed here are based on the dynamic spatial price equilibrium approach and are capable of simultaneous determination of equilibrium market values of 1) consumption, 2) supply,





3) international trade, 4) intertemporal carryover quantities, 5) market prices for each and all commodities, for each and all regions, and for each and all time periods contemplated in the models.

Various examples of practical application are compiled in [9], and most recent results are reported in [19]. This paper is a report of the most recent methodological and empirical works in this research field.

In the following section we formally develop mathematical models that are most frequently employed in our empirical works, and discuss some methodological problems related to our theoretical models. In the third section we discuss data and empirical model structures of one-period and two-period multi-region-multi-commodity world models for 1970-1974 and show the equilibrium solutions in comparison with corresponding actual statistics.

In the concluding section we discuss some of the challenging problems related to projection works that lie ahead of us.



## 2. Dynamic Market-Oriented World Food Projection and Planning Models

In this section a representative model, suitable for market-oriented solutions of present day world food projection and planning problems, will be presented in its skeletal form.

The following definitions and notations are used to formulate this model:

$t, t \in \{0, 1, 2, \dots, T\}$  denote discrete time period (years, months, weeks, or days),

$i, j \in \{1, 2, \dots, N\}$  denote the regions,

$\mu \in \{1, 2, \dots, K\}, v \in \{K+1, K+2, \dots, M\}$

denote the total commodity space and the proper subset of the former, respectively.

Let commodities  $k = 1, 2, \dots, K$  represent final commodities;  $q = K+1, K+2, \dots, Q$  represent intermediate commodities;  $r = Q+1, Q+2, \dots, R$  represent primary mobile commodities;  $m = R+1, R+2, \dots, M$  represent the immobile primary commodities.

$\theta^\mu$  denote the producing and flow processes available for the  $\mu^{\text{th}}$  commodity;  $\mu = 1, 2, \dots, R$ .

$a_{it}^{v\theta^\mu}$  denote the quantity of the  $v^{\text{th}}$  input required for the  $\mu^{\text{th}}$  output emerging per unit of process  $\theta^\mu$  in region  $i$ ;  $v = K+1, K+2, \dots, M$  and  $\mu = 1, 2, \dots, Q$ , at time  $t$ ,

$x_t^{\theta^\mu} = (x_{ij}^{\theta^\mu})_t$  denote the level of process  $\theta^\mu$  that is to flow from region  $i$  to region  $j$ ;  $\mu = 1, 2, \dots, R$ , at time  $t$ ,



- $T_t^{\theta^\mu} = (t_{ij}^{\theta^\mu})_t$  denote the unit transport cost for transporting and the unit marketing margin in selling the  $\mu^{\text{th}}$  commodity produced by process  $\theta^\mu$  from region  $i$  to  $j$ ;  $\mu = 1, 2, \dots, R$ , at time  $t$ ,
- $S_t^\mu = (s_i^\mu)_t$  denote the native availability of commodity  $\mu$  in region  $i$  at time  $t$ ; plant capacity is considered as an immobile primary commodity,
- $b_{it}^\mu$  denote the cost of carrying one unit of the  $\mu^{\text{th}}$  commodity in the  $i^{\text{th}}$  region from  $t$  to  $t+1$ ,
- $y_{it}^k$  denote the consumption quantity of the  $k^{\text{th}}$  final commodity in the  $i^{\text{th}}$  region at time  $t$ .

The natural constraints of the production system at time  $t$  can be expressed as: Final commodity production-consumption constraints:

$$(1a) \quad e_{it}^k \equiv s_{it}^k + \sum_{\theta^k} \sum_j x_{jit}^{\theta^k} - y_{it}^k + x_i^k(t-1, t) - x_i^k(t, t+1) \geq 0, \text{ for all } i, k \text{ and } t,$$

Intermediate commodity production and allocation constraints: 1.a/

$$(1b) \quad e_{it}^q \equiv s_{it}^q + \sum_{\theta^q} \sum_j x_{jit}^{\theta^q} - \sum_{k \neq q} \sum_{\theta^k} a_{it}^{q\theta^k} x_{ijt}^{\theta^k} + x_i^q(t-1, t) - x_i^q(t, t+1) \geq 0, \text{ for all } i, q, \text{ and } t$$

Mobile primary commodity allocation and flow constraints: 1.b/

$$(1c) \quad e_{it}^r \equiv s_{it}^r - \sum_{\theta^r} \sum_j (x_{ij}^{\theta^r} - x_{jit}^{\theta^r}) - \sum_{q \neq r} \sum_{\theta^q} a_{it}^{r\theta^q} x_{ijt}^{\theta^q} - \sum_{q \neq r} \sum_{\theta^q} a_{it}^{r\theta^q} x_{ijt}^{\theta^q} + x_i^r(t-1, t) - x_i^r(t, t+1) \geq 0$$

for all  $i, r$ , and  $t$

---

1.a/ This is the stage the refinery and other production technology coefficients of the type mentioned in Chapter 5 of [20], for food modeling are located.

1.b/ Fertilizers, insecticides, and other mobile primary commodities enter in this stage for food modeling.





Immobile primary commodity allocation constraints:<sup>1.c/</sup>

$$(1d) \quad e_{it}^m \equiv s_{it}^m - \sum_k \sum_j a_{it}^{mk} x_{ijt}^k - \sum_q \sum_j a_{it}^{mq} x_{ijt}^q + x_i^m(t-1, t) - x_i^m(t, t+1) \geq 0$$

for all  $i, m, t$ ,

and  $y_{it}^r, x_i^\mu(t, t+1)$ , and  $x_{ijt}^{\nu\theta\mu} \geq 0$  for all relevant indices.

The constraint system can be expressed in its matrix form as follows:

$$(1) \quad \Psi_X \leq S,$$

where

$$\Psi = \begin{pmatrix} A(1) & & & M(1) \\ & A(2) & & M(2) \\ & & \ddots & \vdots \\ & & & A(T) & M(T) \end{pmatrix},$$

---

<sup>1.c/</sup> Most production factors such as land, capital already sunk in the form of factories, machinery, even labor force in a short run, will fall in this stage.







$I^k, I^{\theta\mu}$  are identity matrices of dimension corresponding to the super-script dimensionality,

$$X \equiv (Y'Z') \equiv [Y(1)' \dots Y(T)' Z(1)' \dots Z(T)']',$$

where

$$Y(\tau) = [y^k(\tau)' x^{\theta^k}(\tau)' x^{\theta^q}(\tau)' x^{\theta^m}(\tau)']',$$

$$\begin{aligned} Z(\tau) &= x(\tau, \tau+1) = [x^k(\tau, \tau+1)' x^q(\tau, \tau+1)' x^r(\tau, \tau+1)' x^m(\tau, \tau+1)']' \\ &= [x_1^1(\tau, \tau+1) \dots x_n^1(\tau, \tau+1) \dots x_1^k(\tau, \tau+1) \dots x_n^K(\tau, \tau+1) \\ &\quad x_1^{K+1}(\tau, \tau+1) \dots x_n^{K+1}(\tau, \tau+1) \dots x_1^Q(\tau, \tau+1) \dots x_n^Q(\tau, \tau+1) \\ &\quad x_1^{Q+1}(\tau, \tau+1) \dots x_n^{Q+1}(\tau, \tau+1) \dots x_1^R(\tau, \tau+1) \dots x_n^R(\tau, \tau+1) \\ &\quad x_1^{R+1}(\tau, \tau+1) \dots x_n^M(\tau, \tau+1)']', \end{aligned}$$

$$S = [S_1' S_2' \dots S_T' ]'.$$

and

$$S_t = [s_t^k' s_t^q' s_t^r' s_t^m' ]'.$$

A static version of the constraint system (1) is a familiar one. Most modelers specializing in the world food or energy linear programming models (see Alan Manne [13], Heady and Egbert [6] and especially Chapter 5 of [20]), but its dynamic counterpart in its present form appears only in Chapter 14 of [20].

The obvious difference is that in the linear programming models,  $y^k$  is a fixed or constant demand quantity vector, but in our model it is a variable vector to be determined endogenously in the system.



We now introduce linear demand functions for the final products as:

$$y_{it} \equiv \begin{bmatrix} y_{it}^1 \\ y_{it}^2 \\ \vdots \\ y_{it}^m \end{bmatrix} = \begin{bmatrix} \alpha_{it}^1 \\ \alpha_{it}^2 \\ \vdots \\ \alpha_{it}^m \end{bmatrix} - \begin{bmatrix} \beta_{it}^{11} & \beta_{it}^{12} & \dots & \beta_{it}^{1m} \\ \beta_{it}^{21} & \beta_{it}^{22} & \dots & \beta_{it}^{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{it}^{m1} & \beta_{it}^{m2} & \dots & \beta_{it}^{mm} \end{bmatrix} \begin{bmatrix} p_{it}^1 \\ p_{it}^2 \\ \vdots \\ p_{it}^m \end{bmatrix}$$

$$\equiv \alpha_{it} - \beta_{it} p_{it} \quad \frac{2/}{},$$

where  $p_{it}^k$  is the price of the  $k^{th}$  produce in the  $i^{th}$  region at time  $t$ , period  $t$ , and  $\beta_{it}$  is assumed to be positive semi-definite only.

With (2) properly estimated or approximated when some of the demand functions were estimated in non-linear forms, we are in a position to establish our market-oriented model(s).

Forms of food and energy markets may range from one extreme, monopoly, to the other extreme, perfectly competitive, and variants of the model to be presented here can be developed for several different forms of the markets. In our model different market forms can be treated indiscriminately in the following definitive framework:

#### Spatial and Temporal Price and Allocation (STPA) Equilibrium:

When the following conditions are satisfied for non-negative  $p_{it}^k$ ,  $\bar{p}_{it}^k$ ,  $\bar{y}_{it}^k$ ,  $\bar{x}_{ijt}^{\theta\mu}$ ,  $\bar{x}_i^{\theta\mu}(t, t+1)$  for all relevant indices the markets are said to be in a STPA equilibrium;

---

<sup>2/</sup> In this model formulation the prices in every region are assumed normalized or standardized in dollar value. This presumes existence of "established" or exchange rates for all the participants in the world trade of food.  $\alpha_{it}$  contains not only an estimated constant in our regression equation but also income effect and time or taste effect terms. Thus we attach the subscript  $t$ .





$$(3.a) \quad \bar{g}_{it}^k \equiv \alpha_{it}^k - \sum_{h=1}^m \beta_{it}^{hk} p_{it}^h - y_{it}^k \leq 0$$

$$\text{and } \bar{g}_{it}^k \cdot p_{it}^k = 0$$

$$(3.c) \quad \bar{e}_{it}^q \geq 0 \text{ and } \bar{e}_{it}^q \cdot \bar{p}_{it}^q = 0$$

$$(3.e) \quad \bar{e}_{it}^m \geq 0 \text{ and } \bar{e}_{it}^m \cdot \bar{p}_{it}^m = 0$$

$$(3.g) \quad \bar{e}_{jit}^{\theta q} \equiv \bar{p}_{it}^q - \sum_{j=1}^{r,m} \bar{p}_{jt}^q a_{jt}^{\theta q} - t_{jit}^{\theta q} \leq 0$$

$$\text{and } \bar{e}_{jit}^{\theta q} \cdot \bar{x}_{jit}^{\theta q} = 0,$$

$$(3.i) \quad \bar{e}_i^\mu(t, t+1) \equiv \bar{p}_{it}^\mu - \bar{p}_{it+1}^\mu - b_{it}^\mu \leq 0$$

$$\text{and } \bar{e}_i^\mu(t, t+1) \cdot \bar{x}_i^\mu(t, t+1) = 0$$

$$(3.b) \quad \bar{e}_{it}^k \geq 0 \text{ and } \bar{e}_{it}^k \cdot \bar{p}_{it}^k = 0$$

$$(3.d) \quad \bar{e}_{it}^r \geq 0 \text{ and } \bar{e}_{it}^r \cdot \bar{p}_{it}^r = 0$$

$$(3.f) \quad \bar{e}_{jit}^{\theta k} \equiv \bar{p}_{it}^k - \sum_{j=1}^{q,r,m} \bar{p}_{jt}^k a_{jt}^{\theta k} - t_{jit}^{\theta k} \leq 0$$

$$\text{and } \bar{e}_{jit}^{\theta k} \cdot \bar{x}_{jit}^{\theta k} = 0$$

$$(3.h) \quad \bar{e}_{jit}^{\theta r} \equiv \bar{p}_{it}^r - \bar{p}_{jt}^r - t_{jit}^{\theta r} \leq 0$$

$$\text{and } \bar{e}_{jit}^{\theta r} \cdot \bar{x}_{jit}^{\theta r} = 0,$$

(where  $\bar{p}_{it}^\mu$  is the market price of the  $\mu^{\text{th}}$  produce in the  $i^{\text{th}}$  region at time  $t$ ) for all relevant indices.<sup>3/</sup>

Our task now is to solve the definitional system (3.a) through (3.i). When  $\beta_{it}$ 's are all symmetric and positive semi-definite, one can use the technique we developed in Chapter 18 of [20]. However, for such a general case as this, we simply proceed to solve the following STPA equilibrium system:

---

<sup>3/</sup> This approach may prove to be less attractive than those we chose in Chapter 18 of the 1971 book, especially to policy decision makers. However, as one can easily show, this and either one of the two approaches (pages 292-295 in [20]) are equivalent to restore the purposive formulation. We contend that the difference in market forms is contained in the expression  $t_{jit}^{\theta \mu}$ 's. For example, under pure monopoly the marketing margin may be much higher than under a perfectly competitive market arrangement.



$$(4.1) \quad \begin{bmatrix} 0 & \psi' \\ \psi & Q \end{bmatrix} \begin{bmatrix} \chi \\ \rho \end{bmatrix} + \begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} \theta \\ S \end{bmatrix}$$

$$(4.2) \quad \rho'v + \chi'u$$

$$(4.3) \quad \text{and } \rho, u, \chi, v \text{ non-negative,}$$

where

$$\rho = [\rho^{k'}, \rho^{k'}, \rho^{q'}, \rho^{n'}, \rho^{m'}]'$$

$Q$  is the matrix with  $\beta_{it}$  properly arranged (see Chapter 18 of [20] for more detail), and

$$\theta = [\alpha_1', T_1', \alpha_2', T_2' \dots \alpha_T', T_T' \quad b_1' \dots b_T' \quad \alpha^{k'}]'$$

In this form my STPA equilibrium system takes exactly the same form as the Lemke-Howson-Cottle-Dantzig "Linear Complementary Problem" [4,12].

In solving the system (4.1)-(4.3) above, however, we do not use the methods suggested by those authors mentioned above in relation to the bimatrix game [20].

The recently developed computer program called MPS III QUAD based on my 1971 book algorithm is now used for large scale models and proves to be efficient. One problem for  $T=1$  with 126 rows in (4.1) form is attached as one example. The computer time on the IBM 370/158 was 16.34 seconds. Another problem with  $T=6$  and 828 rows was solved in 262.95 seconds on the same computer.

The STPA equilibrium model presented above is not completely self-contained. For instance, the demand equations (2) contain various exogenous variables which were condensed into a constant vector  $\alpha_{it}$ . The exogenous variables are usually per capita disposable income the total domestic population in each country or region. Other substitute



or complementary products that were not included in the system, (2), but included in estimation. Time component could be another exogenous variable in many cases before  $\alpha_{it}$  is formed.

$A_i^{\mu\theta v}(t)$  matrices may be highly time dependent in agriculture even though in usual refinery linear programming models they can be considered rather stationary over a considerable length of time. The transportation costs may change quite drastically sometimes, like during the 1973-75 period. Storage costs over time may also change, as we have experienced during the same period as above.  $S_{it}^v$ , mobile and immobile resource availability can change due to, say, national production and resource conservation policy changes.

In many cases this activity based formulation for generating supply may not be suitable or desirable as this formulation basically assumes contemporaneous generation of supply of any commodity ignoring effects of lagged prices and production on the contemporaneous supply. Thus, when the supply functions are estimated with lagged prices and quantities and expressed in their linear system as:

$$(5) \quad x_{it} \equiv \begin{bmatrix} x_{it}^1 \\ x_{it}^2 \\ \vdots \\ x_{it}^m \end{bmatrix} = \begin{bmatrix} \theta_{it}^1 \\ \theta_{it}^2 \\ \vdots \\ \theta_{it}^m \end{bmatrix} + \begin{bmatrix} \gamma_{io}^{11} & \gamma_{io}^{12} & \dots & \gamma_{io}^{1m} & \dots & \gamma_{it}^{11} & \gamma_{it}^{12} & \dots & \gamma_{it}^{1m} \\ \gamma_{io}^{21} & \gamma_{io}^{22} & \dots & \gamma_{io}^{2m} & \dots & \gamma_{it}^{21} & \gamma_{it}^{22} & \dots & \gamma_{it}^{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \gamma_{io}^{m1} & \gamma_{io}^{m2} & \dots & \gamma_{io}^{mm} & \dots & \gamma_{it}^{m1} & \gamma_{it}^{m2} & \dots & \gamma_{it}^{mm} \end{bmatrix} \begin{bmatrix} p_o^{i1} \\ p_o^{i2} \\ \vdots \\ p_o^{im} \\ p_t^{i1} \\ p_t^{i2} \\ \vdots \\ p_t^{im} \end{bmatrix}$$

for all  $t$ ,

then the following changes in (1) through (4) will be required to attain our STPA Equilibrium;





$$(1') \quad \psi x \leq S$$

where

$$\psi = \begin{pmatrix} A(1) & M(1) \\ & A(2) & M(2) \\ & & \ddots \\ & & A(T) & M(T) \end{pmatrix}$$

and

$$A(\tau) = \begin{pmatrix} I_y^k(\tau) & -G_y^k(\tau) & & \\ & -I_x^k(\tau) - G_x^k(\tau) & & \\ & & A^{qk}(\tau) - G^{\theta q}(\tau) & \\ & & A^{\gamma k}(\tau) & A^{\gamma \theta q}(\tau) - G^{\theta \gamma}(\tau) \\ & & A^m{}^k(\tau) & A^{m\theta q}(\tau) \end{pmatrix} \quad \underline{4/}$$

where the subscripts  $y$  and  $x$  refer to demand and supply respectively, and  $G_y^k(\tau)$  and  $G_x^k(\tau)$  are the familiar Koopmans-Hitchcock transport minimization linear programming problem type rectangular matrices corresponding to demand rows and supply rows respectively.

---

<sup>4/</sup>Most likely  $A(\tau)$  takes the following form:

$$A(\tau) = \begin{bmatrix} I_n^k(\tau) & -G_n^k(\tau) \\ & I_x^k(\tau) & -G_x^k(\tau) \end{bmatrix}. \quad \text{For more detail, see the next section.}$$







$$(1a'') \quad e_{itx}^k \equiv s_{it}^k + x_{it}^k + x_i^k(t-1,t) - x_i^k(t,t+1) - \sum_j x_{ijt}^k \geq 0 \text{ for all}$$

$i, k$ , and  $t$  should be employed so as to be consistent with (1').

In  $Y(\tau)$  vector,  $x^{\theta^k}(\tau)$  should be replaced by  $x^k(\tau)$ , and  $S_t^i$  vector should be replaced by

$$S_t = [0' \ S_t^{k'} \ S_t^{q'} \ S_t^{Y'} \ S_t^{m'}]$$

where  $0'$  is a zero row vector corresponding to (1a') and  $S_t^{k'}$  corresponds to (1a'').

Corresponding to these changes, our STPA Equilibrium can be defined in the same way as (3.a) through (3.i) except the second condition (3.b) is replaced by:

$$(3.b) \quad e_{itx}^k \equiv \theta_{it}^k + \sum_t \sum_k \alpha_{it}^{hk} p_{itx}^h - x_{it}^k \geq 0$$

$$\text{and} \quad e_{itx}^k \cdot p_{itx}^k = 0$$

and (3.f) is replaced by

$$(3.f) \quad e_{jit}^k \equiv p_{itx}^k - \sum_v \rho_{jt}^v a_{jit}^{vk} - t_{jit}^k \leq 0$$

$$\text{and} \quad e_{jit}^k \cdot x_{jit}^k = 0.$$

This is an extremely useful formulation which will be used most effectively in our works discussed in the next section.

In this formulation we separated final product price into two components, demand (retail or wholesale) price and supply (wholesale or farm) price. Once this dichotomy is established, the  $t_{jit}^k$  then should be looked upon as the sum of two components, (1) transportation cost and (2) marketing margin. We will come back to this point later in the following section.



With these changes in formulation, notation and definition, we can use essentially the same algorithmic structure as before, that is (4.1), and a solution can be obtained quite efficiently using the MPS III QUAD program.

The attached chart shows a scheme of world food modeling as a component of the dynamic total economic system. The macro-economic model such as the LINK model should be run from time  $t$  to  $t+T$ , where  $T$  is the planning time horizon. Independent of the optimization models, such as we propose here, the macro-economic model will generate the information necessary for the energy, food and other optimization models. Given the information, the STPA Equilibrium models will be solved for equilibrium, consumption, production, trade among countries or regions, carryover quantities from one period to the next, and prices of all the products for all the countries or regions and the time horizon.

In general, goodness or success of the STPA Equilibrium model projections depends crucially on that of the macro-economic model used as exogenous information generator. However, as of now, the models referred to in this paper do not utilize any "established" macro-economic model in a systematic fashion discussed above. Or, on the other hand commodity-oriented simulation models studied by the Wharton School of Economics group have nothing to do with the market-oriented modeling such as we have proposed and applied so far. In the near future, though, we plan to integrate these two models to improve the performance of the future projection models.





### 3. 1970-1974 Model Results

In an attempt to develop reliable projection and planning models for agricultural commodities, we had tentatively<sup>6/</sup> established a few core models that contain most essential components of our theoretical models such as demand coefficients, supply coefficients, transport costs, storage costs, marketing margins, and initial carry-in and terminal carry-over quantities for 1970-1974 crop years. These demand and supply functions, once thrown into our multi-period models, form the simulation component in a programming framework. The coefficients for 1973 and 1974 are recorded in Table 1. An eight commodity one time period two region model for 1974 in (4.1) format is shown in Table 2 along with the computer code for world regions, twenty in number, eight commodities, time period(s) and definitions and statistical sources of variables used in our models in Table 3.

Our first modeling efforts were devoted to test whether our core models are robust enough to reproduce the historical market reality in the United States for 1970-1974.

Tables 4-1 and 4-2 show our tentative<sup>7/</sup> equilibrium solutions of five single period models along with the corresponding actual statistics. The equilibrium solutions are very close to actual statistics except for 1971 when the equilibrium meat prices tend to be a little bit higher than the actual. The equilibrium quantity solutions for U. S. consumption of

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<sup>6/</sup>We stress this simply because projection modeling activities are based on the processes of almost continuous revisions of data file, demand and supply estimates, etc.

<sup>7/</sup>We have at this stage a set of newly estimated coefficients for all the commodities and especially soybean oil for USA and are now installing a new soybean sub-sector modeling strategy for our future work.



all the commodities, and beef and chicken supplies are quite close to the actual. The 1973 and 1974 equilibrium solutions are satisfactory, but the 1972 solutions contained disturbing components; that is, soybean price and quantity consumed. We had used soybean meal price as a proxy to the soybean price (and demand and supply functions were estimated on this data basis), and in 1972 the soybean meal price shot up to \$212 level while the initial solution was just about \$70. In this model we imposed the condition that the soybean meal price should be greater than or equal to \$200. This produced as the dual solution (Remember the primal-dual structure of Table 2!), say "government or industry (who in the industry?) withdrawal from the market", which turned out to be 4.451 million metric tons. Was this the speculative component in the soybean market before the Nixon embargo? We would leave this at this stage as a challenging question to our later studies.

In summary these 1970-1974 models show that, given the import and export quantity and carry-in and carry-over information on all of the eight commodities in the rest of the world, carry-in and carry-over quantities and demand and supply price differentials of all the commodities in the USA, the equilibrium solutions for the commodity prices, consumption and supply quantities are reliably close to the actual statistics. These results are extremely encouraging for developing the full-scale twenty region models.

As a preparatory step to building a full-scale eight commodity, twenty region, two or more time period model, however, we have constructed a two-period, 1973-1974, two region, the USA and the rest of the world, version to test the feasibility and reasonableness of our multi-period dynamic model. For this dynamic modeling we utilize the revised STP equilibrium formulation (1')-(4').



In this model, the demand functions for all the commodities in the USA for both years were in their linear form, and the supply (with time-lagged price variables) functions for all the commodities in the USA for 1974 were incorporated in their linear difference equation form (in price). We also assumed export quantities were known for the USA.

The basic question asked for this model is: What are the equilibrium market prices, consumption, production (1974) quantities, and the carry-over quantities from 1973 to 1974 for the USA for 1973 and 1974 periods.

The actual figures and the model equilibrium solutions are shown in Tables 5-1-4. It is intriguing to know how close these solution prices and quantities, especially the carry-over quantities are to the actual figures. Our models are capable of reproducing the past performance of the US eight commodity markets including the carry-over stocks given certain information on the US and the rest of the world.

There is a basis to believe that a multi-period model tends to improve the model performance in comparison with single period models. However, we do not know yet how long one can stretch the time horizon without overstretching the tentative conclusion we have just reached from this modeling experience. We hope we can answer this question in the next paper.

Two sobering observations from our two region modeling experiences are:

- 1) "Structural changes" have been frequently referred to in relation to the "unexplainable" nature of the agricultural commodities markets. Have we made any use of these structural changes?

The answer is clearly "no".



2) "Uncertainties", "speculations", and "risks" were widely used in explaining "carry-over" behavior of grains. Our perfect foresight and certainty model reproduced the 1973-74 carry-over quantities so accurately. Do stochastic components in real world situations average out and behave as though there were no observably large random effect at all?

We will be dealing with these problems in our future research.

On the strength of these two region models, we have launched into robustness test of our models in their full scale-twenty region-eight commodity framework for 1973 and 1974.

There is a basic difference between two region modeling and a twenty region full scale one. When we model for the two region cases, the rest of the world demand and supply for each commodity are represented by a fixed excess demand or supply quantity relative to the USA. Adding our estimated demand or supply functions to express the rest of the world demand or supply function presumes the existence of trade between the USA and those regions whose demand or supply are expressed in a functional form. To avoid this complication we treated the two region models in such a way that the rest of the world possesses fixed excess demand (or supply) quantities for each and all commodities; quantities being perfectly inelastic to price changes (another extreme is the traditional international trade theory [10] that assumes perfectly elastic foreign demand functions!). In our twenty region models we free the rest of the world from this spell. Thus, as already shown in Table 1, the coefficients of demand and supply functions for some regions and commodities are introduced into our twenty region models.





Additional data requirements are tremendous once we move into this stage. Ocean freight costs, storage costs, marketing margins, carry-in and carry-over (stock), these crucial statistics are rather country or region specific and it is not easy to collect reliable data for our use. However, within this restriction we applied our model to the world food situations of 1973 and 1974. The results for single period 1973 and 1974 models are shown in Tables 6 and 7, respectively, and the two period, 1973-1974 model results in Table 8.

By checking through the 1973 and 1974 single period equilibrium solutions vis-a-vis actual statistics, one can conclude that these models can reproduce actual price and allocation situations rather accurately. This is especially true for the U. S. market situations. Trade flows look reasonable. However, due to the lack of consistent statistics or the sheer lack of them for some regions, we have recorded a partial list of actual flows in parentheses directly below the equilibrium flows in the wheat flow tables (for other commodities, refer to the authors).

In the case of our two region two period, 1973-1974 model reported before, we expressed our view that a multi-period model tends to improve the single model performance. And in this full-scale modeling case we found rather confusing pictures appearing in the solutions; that is, the 1973-1974 equilibrium carry-over quantities of wheat, maize, other coarse grains and soybeans in the USA are much lower than these corresponding actual figures.

In this two period modeling work we assumed perfect foresight for each and all the participants in the world trade both in spot and future markets. At the same time, we ignored practically acceptable



minimum pipeline carry-over quantity of any product, transport capacities from one source region to other regions (capacitated network), and storage capacities in any region in the model.

Thus, contrary to our expectation, the 1973-1974 model solutions based on the no pipeline carry-over assumption, which due to the space limitation are not shown in this paper, exhibit disappointing performance in the equilibrium carry-over stocks for these important grains. The main causes were pointed out in the last paragraph. However, the main reason for this discrepancy between the two region model and the twenty region model is that the latter determines the equilibrium trade quantities for each year endogenously and allows the equilibrium solutions rather wide deviations from the historical statistics. For instance, the equilibrium solution for the 1973 U. S. wheat carry-over is zero while the actual was 6.722 million metric tons. In this case, the equilibrium Canadian carry-over is more than 18 million metric tons, and the equilibrium European Community is slightly more than 6 million metric tons. If the model allows more favorable conditions for any commodity in some regions to be stored in the regions than actually existed (due mainly to lack of information), then that commodity can profitably be moved to those regions in the first year, in the case of wheat and maize, and is carried over in those regions to the next year and consumed.

As the last experiment with our first model using the coefficients compiled in Table 1, we incorporated pipeline carry-over quantity constraints of the following magnitudes:



Wheat	Maize	Other Grains	Soybeans	
6	10	7	4	(million metric tons)

Obviously, due to our primal-dual way of modeling the world markets these constraints create their counterpart administrative costs of realizing these pipeline carry-over quantities.

The solutions recorded in Tables 8-1 and 8-10 are much more reasonable in this model than the original model.<sup>8/</sup>

We are almost continuously alerted by our model solutions that something is missing in our data or the data used are not correct (human error or otherwise). The data may not always be purely economical. Sometimes export or import policies, such as embargo, subsidies, import tariffs, import quota, etc., may play very important roles.

We also admit that the model performances are not quite satisfactory in chicken, other coarse grains, and soybeans. The reasons for poor performances may be different. For instance, trying to capture and reproduce the U. S. chicken industry which has shown several production turnovers per year in our annual models is a difficult task unless the industry shows stationary characteristics in both prices and quantities. In the case of other coarse grains, the aggregation of sorghum, oats, and barley makes the statistical performance of the demand and supply functions rather poor, which in turn affects the model performance. The case of soybeans is different from the other two. The joint production nature of soybean meal and soybean oil is the basic cause of poor performance of soybean industry in our model. We are in the process of improving our modeling by separating soybean meal from oil in demand functions. In this case, we are also using activity analysis formulation to generate supply of meals and oil from soybeans. These are only

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<sup>8/</sup>Trade tables for this two-period model are not recorded in this paper.



a few improvements we have been making so far, and in the concluding section to follow we plan to mention some of the more challenging problems and research work we are and will be engaging with respect to our world food projection work.

In concluding our model experimentations we report the test results of five hypotheses related to policy intervention of the markets. The first three cases deal with quantity oriented policy exercises, while the fourth and fifth cases deal with traditional price support policies. Only partial solutions are shown in Table 11.

#### Case 1

US is assumed to maintain the end of 1973 wheat stock level but decrease the maize stock level by about three million metric tons to the stock level of 1974.

The retail price of wheat in US declined from \$141.9 (basic model solution) to \$127.7 per ton. Similar price decreases take place in other regions. The ratio of percentage price change to the percentage quantity change, price flexibility of stock adjustment,  $(-14.2/141.9)/(-2.178/19.310) = .89$ , shows that if the 1974 wheat carry-over was to be 10% lower than the equilibrium one the price would have been 8.9% lower than the equilibrium price. This information may be useful in reserve operation.

#### Case 2

Contrary to case 1, we assumed that the maize stock remained the same as the 1974 beginning stock of 12.258 million metric tons, that is the increase of 3.149 million metric tons over and above the actual 1974 ending stock of 9.109 million metric tons, but the wheat end of the year 1974 stock remained the same, 8.900 million metric tons, as the actual.





Naturally, the price of maize will go up from that in the basic model, and that of wheat will go down in this situation. However, the assumptions made in case 2 do not affect prices as much as those in case 1. The price flexibility,  $(+4.4/92.5)/(+3.149/9.109) = .14$ , shows that 10% carry-over quantity change will induce 1.4% price change in the US maize market. Cases 1 and 2 reveal the internal structure of US grain market; wheat market is six times more price sensitive than the corn market, explaining a great deal of 1973-1974 grain market situation.

### Case 3

In this case we assumed that the wheat and maize stock levels at the end of 1973 were maintained to the end of 1974. That is, from the end of the year 1974 stock point of view, the 2.178 million metric tons decrease of wheat stock and 3.149 million metric tons increase of maize stock are assumed occurring simultaneously. This case results in practically the same price for wheat as in case 1, and the same price for maize as in case 2.

### Case 4

Let us assume now that the US decided to carry exactly the same amount of wheat and maize as in 1974, but for some reason decided also to maintain the market price at \$175 per metric ton for wheat.

This assumption forces the model to add one price constraint for US. The consequent change in quantity is generated to express the required withdrawal or carry-over of wheat by, say, the Wheat Board or the government agency.

In this case, 5.153 million metric tons of wheat was withdrawn from the 1974 wheat market to realize the \$175 price which is about 20% higher than the 1974 equilibrium price. In terms of price



flexibility, we have  $(+33.1/141.9)/(+5.153/19.310) = .89$  almost the same as the previous carry-over operation (case 1; .89). Another interesting feature is that this operation leaves the maize market almost intact. Thus, from the policy choice point of view, the US wheat price target can be attained by either carry-over (stock) adjustment policy or government withdrawal of wheat policy. In either case the cost to the government should be almost the same. Which approach is more politically feasible and easily adaptable is a question of quite a different nature.

#### Case 5

The assumption that the government or marketing board wants the maize price to be \$120 per metric ton is tested here. Based on the observation made in case 2, the expected result is that a larger withdrawal of maize is required to accomplish this objective than was required for wheat in case 4. The price flexibility of maize is  $(+27.5/92.5)/(+19.576/9.109) = .14$  in this case and is almost exactly the same as in case 2.

From these observations, we may be able to conclude that, if our model is correct, it is less costly to manipulate the wheat market than the corn market through either quantity withdrawal or discharge on price fixing policy.

These five cases dealt with in this section are only a few examples of policy exercises or evaluations one can perform by using our market-oriented world food models.



#### 4. Concluding Remarks

In this paper our main objectives were twofold: 1) to tentatively establish our core world food projection models, and 2) to test the robustness of our models by applying them to actual food market situations of 1970-1974.

The basic importance of our modeling methodology is that all the eight important commodities are handled simultaneously, and all the twenty regions are connected over space and time in the system. These properties, simultaneity and interconnectedness over space and time, are essential components of any world food (or energy) models. This fact has been recognized for some time, but no such system has been developed to satisfy these requirements and actually applied to real world situations.

We feel that we have created, with some success, the first generation world agricultural commodity core models. We have been concentrating on improving on various aspects of the models since February 1976.

We want to discuss at this stage several points which require further comments and more detailed study in order for new developments to improve our present model.

First, in this modeling we had no way of knowing that the coefficient matrix formed by the demand and supply equations requires the conventional stability condition. The very initial set of equations had just one unstable mode. This equation was re-estimated and the instability resolved. This finally produced the initial set of solutions we have been dreaming about. This reveals that the test of stability of the system, especially the demand and supply system, <sup>9/</sup> may be essential before starting to solve the system.

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<sup>8/</sup> It is clear from our LCP structure testing the stability of this subsystem is sufficient. For a single period case, see [17]. However, later models reveal that this test may not be necessary. We will report more on this point in our later work.



Second, due to the well-known elasticities of all the commodities involved, the system is fairly sensitive to a small change in transport cost, marketing margins, and government tax or subsidies, and very much sensitive to a small change of end of the year stocks and a sudden change of supply of a certain commodity in a region of the world, etc. This would naturally force us to investigate more carefully the relative importance of these factors in determining the market outcomes.

Third, it would be worthwhile to open up a new theoretical and empirical investigation of estimator efficiencies related to our model. In this study we chose only the ordinary least squares estimator and obtained the results we consider quite satisfactory. Naturally, we are intrigued to know which estimator among many would perform best for our world model.

Finally, the present model is our first generation annual model. Since the world still consists of the northern and southern hemispheres, we have to go at least one step further to construct and establish our semi-annual model in the near future. The benefit is obvious. A short run semi-annual model would reflect harvest expectation of the other hemisphere and the carry-over quantities can be quickly adjusted to the expected situation.

Another point that is closely related to the concept of expectation is the stochastic nature of the agricultural production talked about for several decades now since the time of T. W. Schultz [16]. There are many standard ways of handling stochastic systems (see [1] for the most recent development), but these standard approaches do not seem to contribute to the further understanding nor do they





facilitate actual decision-making (but do not lead to a no-decision making situation) by many policy makers. The main reason for the need and use of the stochastic component in policy decision making areas for agriculture is "stabilization policies" related to "reserve policies". Traditionally, the stabilization theorists based their arguments on (1) existence of static, stationary demand and supply functions existing for all time periods in the infinite future, and (2) existence of errors in demand and/or supply functions whose expectations exist at least up to the second order. They also concentrated on a single commodity market. These bases are rather unfounded in the face of simultaneity of commodity markets, continuous population growth and income changes. A new step should be taken in this area by taking advantage of our dynamic models to generate dynamic equilibrium paths of prices and quantities over time and then analyze the stabilization policies in reference to these dynamic paths. In the next report we plan to investigate this stabilization policy issue to some extent.

Another point we have ignored so far is national planning modeling for those countries importantly involved in international trade of agricultural commodities. We believe that the most efficient way to handle this is to construct a rather comprehensive regional model for the nation and connect this with a simplified version of the international model such as we reported here. This way national planning or projection can be accomplished without becoming as extremely myopic as many planning models have been.

We also ignored the question of how competitive the commodity markets have been and will be. In our later reports we intend to bring this topic up singly and thoroughly analyze it.



Our research work leads us toward projections for 1980, 1985, 1990, etc., and we are prepared to gear our activities to squarely meet this challenge. In the next report we plan to fully discuss problems related to projection works in distinction to our present robustness test work.



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Table 1.  
Confidence Intervals for Demand and Supply Functions for 1973-1974 Twenty Region-High Commodity Model

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For codes used in this table, see Table 3-1 "3.



[illegible]









Table 3-1

Explanation of Codes in the World Food Model  
(8 Commodities and 20 Regions)

Structure of Row and Column Names

1. Prices

Example:

Regional supply price of beef in the U.S.  
at time 1

On cards: RDBU1

On print out: PRDBU1

QMATGEN	Identification	Price Code	Economic	Activity Code	Commodity Code	Country Code	Time Code
---------	----------------	------------	----------	---------------	----------------	--------------	-----------

2. Consumption and Production

Example:

Consumption of beef in the U.S. at time 1

On cards: DBU1

On print out: XDBU1

QMATGEN	Identification	Economic	Activity Code	Commodity Code	Country Code	Time Code
---------	----------------	----------	---------------	----------------	--------------	-----------

3. Trade

Example:

Export of wheat from U.S. to Canada at time 1

On cards: TWUC1

On print out: XTWUC1

QMATGEN	Identification	Economic	Activity Code	Commodity Code	Country Code (Export)	Country Code (Import)	Time Code
---------	----------------	----------	---------------	----------------	--------------------------	--------------------------	-----------

4. Carry-Over

Example:

Carry-over of wheat in U.S. from time 1 to  
time 2

On cards: ZWUC1

On print out: XZWUC1

QMATGEN	Identification	Economic	Activity Code	Commodity Code	Country Code	Time Code (From)	Time Code (To)
---------	----------------	----------	---------------	----------------	--------------	---------------------	-------------------





Table 3-2

Codes

## 1. QMATGEN identification

Primal var. (columns): x for Cons., Prod., Trade; p for S and D prices.

Dual var. (rows): v for Cons., Prod., Trade; y for S and D prices

## 2. Prices codes

R = Regional, M = Market price, F = price of commodities which have fixed excess demand (or supply)

## 3. Economic activity code

a) for prices: D = Demand, S = Supply Price

b) for consumption and production: D = Consumption, S = Production

c) for trade: T = Trade flow from . . . to . . .

d) for carry-over: Z = carry-over from . . . to . . .

## 4. Commodity code

B = beef

M = maize

P = pork

G = coarse grains

C = chicken

S = soybeans

W = wheat

R = rice

## 5. Time code

for one period model: 1

## 6. Countries

U USA

I S. Asia

C Canada

D N. Africa & Middle East (high income)

E EC 9

N " " (low income)

W Other W. Europe

F Other Africa

S South Africa

M Central America

J Japan

B Brazil

Z Australia - New Zealand

G Argentina

H East Europe

L Other South America

R USSR

K Communist Asia

A East Asia

T Thailand



Definition of VariablesU.S.

- $P_B$ : Estimated weighted average prices of choice beef cuts in \$/MT\*\*\* -- Livestock and Meat Situation
- $P_B^B$ : Average price received by farmers for beef cattle in \$/MT\*\* -- Livestock and Meat Situation
- $P_P$ : Estimated weighted average price of retail pork cuts and sausage in \$/MT\*\*\* -- Livestock and Meat Situation
- $P_P^P$ : Price of barrows and gilts at seven representative markets in \$/MT\*\* -- Livestock and Meat Situation
- $P_C$ : Liveweight average broiler price at farm in \$/MT\*\*\* -- Poultry and Egg Situation
- $P_C^C$ : Liveweight average broiler price at farm in \$/MT\*\* -- Poultry and Egg Situation
- $P_W$ : Weighted average price of wheat at selected markets for all grades in \$/MT\*\* -- Survey of Current Business
- $P_W^W$ : U.S. season average price for wheat received by farmers for all grades in \$/MT\*\* -- Wheat Situation
- $P_M$ : Average price of corn at selected markets for all grades in \$/MT\*\* -- Survey of Current Business
- $P_M^M$ : Average season price for corn received by farmers for all grades in \$/MT\*\* -- Feed Situation
- $P_G$ : Average weighted price of grain sorghum by sales received by farmers in \$/MT\*\* -- Feed Situation
- $P_G^G$ : Average weighted price of grain sorghum by sales received by farmers in \$/MT\*\* -- Feed Situation
- $P_S$ : Price per ton of 44% protein soybean meal at Decatur\*\* -- Fats and Oils Situation
- $P_S^S$ : Average season price of soybeans received by farmers in \$/MT\*\* -- Fats and Oils Situation
- $P_R$ : Season average of rough rice prices received by farmers in \$/MT\*\* -- Rice Situation

---

\*\*Prices have been deflated by Wholesale Price Index with 1970 = 100 -- Current Survey of Business

\*\*\*Prices have been deflated by Consumer Price Index with 1970 = 100 -- Current Survey of Business



Y: Per Capita annual personal consumption expenditures (seasonally adjusted)  
in \$\* -- Survey of Current Business

L<sub>B</sub>: All cattle on farms as of January 1 -- Livestock and Meat Situation

L<sub>P</sub>: All swine on farms as of December 1 -- Livestock and Meat Situation

Canada

P<sub>W</sub>: Export price of wheat, No. 7 Northern in U.S. \$/MT\*\*\* -- F.A.O., Production Yearbook

Italy and West Germany

P<sub>W</sub>: Wholesale price of wheat (domestic wheat, EC standard quality, at Milano for Italy and at Dortmund for West Germany)\*\* -- Statistical Office of European Communities, Agricultural Statistics

Japan

P<sub>W</sub>: Government's selling prices of domestic wheat and imported wheat (Western White). The weighting factors are: .1 for domestic wheat and .9 for imported wheat. \$/MT\*\*\*\* -- Government's report

P<sub>R</sub>: Government's selling price of brown rice (non-glutinous rice)\*\*\*\* -- Government's report

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\*Income is expressed in terms of 1970 dollars P.C.E. deflator was used --  
Current Survey of Business

\*\*Prices have been deflated by Consumer Price Index with 1970 = 100 -- O.E.C.D.,  
Main Economic Indicators

\*\*\*Prices have deflated by Consumer Price Index with 1970 = 100 -- I.M.F.,  
International Finance Statistics

\*\*\*\*Prices have been deflated by Consumer Price Index in Tokyo with 1970 = 100,  
Japan Statistical Yearbook



Table 4-1. Actual and Equilibrium Prices of the Eight-Commodity, Two-Region Model for 1970 Through 1974; US.  
(1970 dollar/metric ton = MT)

	1970	1971	1972	1973	1974					
	Actual	Equil. solution	Actual	Equil. solution	Actual	Equil. solution				
<u>Demand Price</u>										
Beef	2,174	2,455	2,205	2,420	2,329	2,385	2,610	2,624	2,410	2,495
Pork	1,720	1,837	1,486	1,525	1,702	1,925	2,115	2,221	1,878	1,939
Chicken	300	408	290	300	289	427	462	440	373	398
Wheat	66	70	61	60	64	88	110	96	140	155
Maize	52	62	52	60	46	50	68	67	85	95
Other grains	45	45	40	57	50	62	69	60	76	92
Soybeans	79	75	87	52	212	200	120	81	90	121
Rice	190	190	190	190	263	263	475	475	306	306
<u>Supply Price</u>										
Beef	597	879	620	835	685	740	773	787	541	626
Pork	500	618	374	413	513	735	694	799	520	582
Chicken	300	408	293	282	288	426	434	411	327	352
Wheat	49	53	47	45	60	84	119	106	102	117
Maize	52	62	41	49	57	50	82	81	80	90
Other grains	45	45	40	57	50	62	69	60	76	92
Soybeans	105	101	108	73	149	137	171	132	158	190
Rice	114	114	114	114	138	138	130	130	235	235





Table 4-2. Actual and Equilibrium Quantities of the Eight-Commodity, Two-Region Model for 1970 Through 1974, US.  
(1000 metric tons)

	1970		1971		1972		1973		1974	
	Actual	Equil. solution	Actual	Equil. solution	Actual	Equil. solution	Actual	Equil. solution	Actual	Equil. solution
<u>Demand Quantity</u>										
Beef	10,838	9,981	10,869	10,370	11,193	10,991	10,591	10,794	11,406	10,927
Pork	6,168	6,101	6,853	6,709	6,391	6,169	5,851	5,746	6,379	6,247
Chicken	3,769	3,567	3,789	3,714	3,989	3,581	3,880	4,100	3,929	3,994
Wheat	21,239	20,607	22,539	23,256	23,304	20,988	20,466	20,467	18,507	18,399
Maize	101,015	109,345	111,429	111,439	120,218	120,252	117,627	117,628	92,481	92,430
Other grains	39,766	40,881	38,840	37,702	37,436	36,919	37,501	37,302	28,150	27,712
Soybeans	13,046	22,602	13,110	17,585	11,921	17,122	16,792	18,858	15,202	13,128
Rice	1,560	1,560	1,606	1,606	1,619	1,619	1,664	1,664	1,823	1,823
<u>Supply Quantity</u>										
Beef	9,836	9,462	9,934	9,778	10,166	10,408	9,651	10,215	10,495	10,458
Pork	6,101	6,101	6,709	6,709	6,169	6,169	5,746	5,746	6,247	6,247
Chicken	3,821	3,567	3,821	3,714	4,055	3,581	3,963	4,100	3,914	3,995
Wheat	40,652	40,652	34,102	34,102	53,243	53,243	50,546	50,546	43,138	43,138
Maize	122,375	122,375	131,632	131,632	152,180	152,180	149,175	149,175	121,615	121,615
Other grains	46,272	46,272	41,900	41,900	43,739	43,739	46,004	46,004	34,128	34,128
Soybeans	34,240	34,240	32,735	32,725	34,916	34,916	39,078	39,078	32,678	32,678
Rice	2,580	2,580	2,910	2,910	2,827	2,827	2,767	2,767	3,423	3,423



Table 5-1  
Eight-Commodity, Two-Region, Two-Period Model  
1973-1974 Prices

(unit: \$/MT)<sup>a/</sup>

	1973		1974	
	Actual	Equil. solution	Actual	Equil. solution
<u>U.S.</u>				
Demand Price:				
Beef	2610	2655	2410	2455
Pork	2115	2248	1878	1749
Chicken	462	461	373	335
Wheat	110	105	140	135
Maize	68	70	85	87
Other coarse grains	69	67	76	74
Soybeans	120	110	90	79
Rice				
Supply Price:				
Beef	773	818	541	586
Pork	694	826	520	399
Chicken	434	432	327	289
Wheat	119	114	102	97
Maize	82	84	80	82
Other coarse grains	69	67	76	74
Soybeans	171	161	158	148
Rice				

<sup>a/</sup> MT = metric ton.



Table 5-2  
Eight-Commodity, Two-Region, Two-Period Model  
1973-1974 Quantity

(unit: 1000 MT)

	1973		1974	
	Actual	Equil. Solution	Actual	Equil. Solution
<u>U.S.</u>				
Demand Quantity:				
Beef	10591	10701	11406	11015
Pork	5851	5746	6379	6549
Chicken	3880	4085	3929	4034
Wheat	20466	20557	18507	18723
Maize	117627	117214	92481	95738
Other Coarse Grains	37501	36076	28150	31560
Soybeans	16792	17792	15202	15159
Rice				
Supply Quantity:				
Beef	9651	10233	10495	10436
Pork*	5746	5746	6261	6549
Chicken**	5089	4085	5135	4034
Wheat***	45347	45347	48800	45730
Maize	143434	143434	118466	121360
Other Coarse Grains	42492	42492	31508	34130
Soybeans	42107	42107	33061	34027
Rice				

\*Export figures have been subtracted.

\*\*Figures have been converted into "chicken ready to cook" basis.

\*\*\*Figures of non-commercial trade have been subtracted.



Table 5-3  
Eight-Commodity, Two-Region, Two-Period Model  
1973-1974 Export Quantity

(unit: 1000 MT)

	1973		1974	
	Actual	Equil. Solution	Actual	Equil. Solution
<u>U.S.</u>				
Export Quantity:				
Wheat***	30079	30079	24739	24739
Maize	31547	31547	29185	29185
Other Coarse Grains	8702	8702	6416	6416
Soybeans	20220	20220	19550	19550
Import Quantity:				
Beef	579	579	468	468

Non-commercial trade quantities are subtracted.





Table 5-4  
1973-1974 Carry-Over Quantity  
 (unit: 1000 MT)

	From 1973 to 1974	
	Actual	Equil. solution
<u>U.S.</u>		
Storage Quantity:		
Beef	209	111
Pork	130	0
Chicken	14	0
Wheat	6722	6632
Maize	12268	12682
Other Coarse Grains	7843	9069
Soybeans	4651	5717



MODEL: 8-Commodity, 20-Region

Table 6-1

Year: 1973

Commodity: Beef, Pork, Chicken, and Rice

(Unit: 1000 MT)

Region	Carry-in		Supply		Demand		Carryover		Prices (US\$/MT)			
									Supply		Demand	
	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium
BEEF												
U			9,561	10,259	10,591	10,556			773	867	2,610	2,704
C					36	36						2,704
E					576	575						2,704
W					169	169						835
J					127	127						2,704
Z			785	785						435		
M			27	27						2,304		
B			97	97						2,304		
G			294	294						435		
PORK												
U			5,746		5,851	5,746			694	865	2,115	2,286
CHICKEN												
U			3,963	4,065	3,880	4,065			434	462	462	491
RICE												
U			2,767	1,103	1,664				130	130	475	475
J			10,995	10,995	11,365	10,995			130	170	352	391
A					1,103	1,103						146



Commodity: Wheat

Prices (US\$/MT)

[illegible]



Commodity: Maize

(Unit: 1000 MT)

[illegible]





Table 6-4

Commodity: Other Grains

(Unit: 1000 MT)

[illegible]



Table 6-5

Commodity: Soybeans

[illegible]



Table 6-6. Equilibrium Trade Flows  
 Model: 8-Commodity, 20 Region Year: 1973 (1000 MT)

IM EX	U	C	E	W	S	J	Z	H	R	K	A	T	I	D	N	F	M	B	G	L
SOYBEANS																				
U	18,859	290	9,730	3,894		6,305														
B						3,474														
RICE																				
J						10,995														
BEEF																				
U	10,267																			
Z	2	36	451			127														
M			28																	
B			97																	
G	294																			
PORK																				
U	5,746																			
CHICKEN																				
U	4,066																			
MAIZE																				
U	116,304	1,266	11,832	6,087	17	3,964		76	4,843	2,073	147			276	634		1,656			
T											2,131									
B																				42
G																177				643



Table 6-7. Equilibrium Trade Flows  
Model: 8-Commodity, 20-Region Year: 1973 (1000 MT)

IM EX	U	C	E	W	S	J	Z	H	R	K	A	T	I	D	N	F	M	B	G	L	O
	U	C	E	W	S	J	Z	H	R	K	A	T	I	D	N	F	M	B	G	L	O
WHEAT																					
U	19,257			0	0	0		0		118	3,445	93	6,578	3,780	6,174	1,379	1,596	2,133		3,276	2,711
C		6,651	2,587	0	0	0		0		5,688	0		0	0	0	0	0	0		0	97
E			39,999																		
J						262															
Z						5,672															
Z											1,207										
R								4,140					110					677			
G																					
OTHER GRAINS																					
U	40,464					4,396									962	131			51		
C			744			382		713	964												
Z						1,123					406		911								
T											188										
F															499						
G																	379				594







Year: 1974

Commodity: Beef, Pork, Chicken, and Rice

(Unit: 1000 MT)

ion	Carry-in		Supply		Demand		Carryover		Prices (US\$/MT)			
									Supply		Demand	
	Actual	Equi- librium	Actual	Equi- librium	Actual	Equi- librium	Actual	Equi- librium	Actual	Equi- librium	Actual	Equi- librium
BEEF												
			10,495	10,414	11,406	11,159			541	545	2,410	2,414
					33	33						2,414
					48	48						2,414
					54	54						2,414
			677	677						145		
			14	14						145		
			79	79						145		
			110	110						145		
PORK												
			6,247		6,379	6,247			520	541	1,878	1,891
CHICKEN												
	4,002											
RICE												
			3,423	1,600	1,823				235	235	306	306
			11,136	11,136	10,902	11,136			142	391	285	391
					1,600	1,600						251



Table 7-2

Commodity: Wheat

(Unit: 1000 MT)

[illegible]



Table 7-3

Commodity: Maize

(Unit: 1000 MT)

[illegible]



Commodity: Other Grains

(Unit: 1000 MT)

[illegible]







Commodity: Soybeans

[illegible]



Table 7-6. Equilibrium Trade Flows  
Model: 8-Commodity, 20-Region Year: 1974 (1000 MT)

	U	C	E	W	S	J	Z	H	R	K	A	T	I	D	N	F	M	B	G	L	O
U	19,328					5,415						100	2,395	343	6,743	1,567	1,585			2,937	2,725
C		5,335								5,942			5,081								
E			42,702											597							
W								189										43	2,082		
G																					
J						212															
Z										4,680				4,670							
R							2,826						1,499								

MAIZE

U	90,540	1,240	12,636	117	17	7,200		3,180	2,000	600	226			487	472		2,900				
T											1,900										
B				1,080																670	
G				4,968												431					

OTHER GRAINS

U	26,409		839			4,273								1,425	146		589	10		437	
C			57	797				1,473	30												
Z										625			501								
T										230											
E													49								



(1000 MT)

[illegible]



MODEL: 8-Commodity, 20-Region, 2-Period

Table 8-1

Year: 1973

Commodity: Beef, Pork, Chicken, and Rice

(Unit: 1000 MT)

Region	Carry-in		Supply		Demand		Carryover		Prices (US\$/MT)			
									Supply		Demand	
	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium
BEEF												
U			9,651	10,259	10,261	10,555		0	773	864	2,610	2,701
C					36	36						2,701
E					576	576						2,701
W					169	169						832
J					127	127						2,701
Z			785	785						432		
M			28	28						2,301		
B			97	97						2,301		
G			294	294						432		
PORK												
U			5,746	5,746	5,851	5,746			694	892	2,115	2,313
CHICKEN												
U			3,963	4,024	3,880	4,024			434	494	462	523
RICE												
J			10,995	10,995	11,365	10,661		334	130	203	352	425
A					1,601	1,601						146





MODEL: 8-Commodity, 20-Region, 2-Period

Commodity: Wheat

[illegible]



MODEL: 8-Commodity, 20-Region, 2-Period

Commodity: Maize

[illegible]



MODEL: 8-Commodity, 20-Region, 2-Period

Commodity: Other Grains

(Unit: 1000 MT)

[illegible]





Table 8-5

Commodity: Soybeans

(Unit: 1000 MT)

[illegible]





MODEL: 8-Commodity, 20-Region, 2-Period

Table 8-6

Year: 1974

Commodity: Beef, Pork, Chicken, and Rice

(Unit: 1000 MT)

Region	Carry-in		Supply		Demand		Carryover		Prices (US\$/MT)			
									Supply		Demand	
	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium	Actual	Equi-librium
BEEF												
U			10,495	10,779	11,406	11,524			541	419	2,410	2,288
C					33	33						2,288
E					48	48						2,288
J					54	54						2,288
Z			677	677								
M			14	14								
B			79	79								
G			110	110								
PORK												
U			6,247	6,532	6,379	6,532			520	260	1,878	1,610
CHICKEN												
U			3,914	4,133	3,929	4,134			327	164	373	210
RICE												
U				3,152					235	235	306	306
J			11,136	11,136		11,470				215	285	358
A					1,601	1,601						251



Table 8-7

Commodity: Wheat

Prices (US\$/MT)

[illegible]



MODEL: 8-Commodity, 20-Region, 2-Period

Commodity: Maize

(Unit: 1000 MT)

[illegible]



Table 8-9

Commodity: Other Grains

(Unit: 1000 MT)

[illegible]







Table 8-10

Commodity: Soybeans

(Unit: 1000 MT)

[illegible]



Table 11. Effects of Hypothesized Floor Price and Stock Situations, US and Japan, 1974.

	Basic Model	Case 1	Case 2	Case 3	Case 4	Case 5
1,000 MT						
<u>Stock change</u>						
Wheat (US)	+2,178	0 <sup>a/</sup>	+2,178	0	+2,178	+2,178
Maize (US)	-3,149	-3,149	0 <sup>a/</sup>	0	-3,149	-3,149
Dollars per MT						
<u>Demand price</u>						
Wheat (US)	142	128	142	128	175 <sup>a/</sup>	142
Maize (US)	93	93	97	97	93	120 <sup>a/</sup>
Wheat (Japan)	101	87	101	87	134	101
Beef (US)	2,414	2,414	2,413	2,413	2,414	2,403
Pork (US)	1,890	1,890	1,905	1,905	1,890	1,979
Chicken (US)	367	367	839	384	367	474
1,000 MT						
<u>Consumption</u>						
Wheat (US)	19,310	20,712	19,366	20,717	15,993	19,335
Maize (US)	90,540	90,540	87,391	87,391	90,540	70,964
<u>Export</u>						
Wheat (US)	23,908	22,506	23,852	22,501	22,072	23,883
Maize (US)	33,667	33,667	36,816	36,816	33,667	33,667
Government withdrawal					5,153	19,576

<sup>a/</sup> Newly tested hypothesis.















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